The selective wavelength method and evaluation of displaying color in time in computer color match prediction*

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In practice, it is found that equal reflective energy variation of each wavelegth has some different effects on the color of objects. Some wavelengths play such an important role in color that their small energy variation can change obviously the color appearance of object. By virtue of computer color match prediction technique, the theory of uniform color system and the appropriate mathematical method, an optimal sensitive wavelength match method in dye or paint industry is studied. In the light of the relationship between tristimulus values of red, green and blue phosphors and the R, G, B values of the three electronic guns of a displaying computer system, in the note, a corresponding color to the computer match prediction recipe is displayed in order to make a subjective evaluation and select an optimal recipe.

1 Theoretical analysis

1.1 Sensitivity

Naturally, the color difference ΔE 1976 (L^*, a^*, b^*) color space should be an ideal evaluation function[1]

$$\begin{cases} L^*=116(Y/Y_0)^{1/3}-16=L(Y), \\ a^*=500((X/X_0)^{1/3}-(Y/Y_0)^{1/3})=A(X,Y), \\ b^*=200((Y/Y_0)^{1/3}-(Z/Z_0)^{1/3})=B(Y,Z), \end{cases} \tag{1.1}$$

and

$$\Delta E=((\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2)^{1/2}, \tag{1.2}$$

Making differentiation with respect to eqs. (1.1), we obtain

$$\begin{cases} \Delta L^*=L'(Y)\Delta Y, \\ \Delta a^*=A'x(X,Y)\Delta X+A'y(X,Y)\Delta Y, \\ \Delta b^*=B'y(Y,Z)\Delta Y+B'z(Y,Z)\Delta Z, \end{cases} \tag{1.3}$$

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where

$$\begin{cases} \Delta X = k\sum S(\lambda)\bar{x}(\lambda)\Delta R(\lambda)\Delta\lambda, \\ \Delta Y = k\sum S(\lambda)\bar{y}(\lambda)\Delta R(\lambda)\Delta\lambda, \\ \Delta Z = k\sum S(\lambda)\bar{z}(\lambda)\Delta R(\lambda)\Delta\lambda. \end{cases} \tag{1.4}$$

k is the adjustment factor; $S(\lambda)$ the relative spectral power distribution of light sources; $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ are the spectral tristimulus values of standard observer; $\Delta R(\lambda)$ is the spectral reflectance variation of objects; $\Delta\lambda$ the wavelength interval.

Through combination of eqs. (1.2)—(1.4) with (1.1), the color difference ΔE of each wavelength caused by a given equal spectral reflectance variation can be calculated, and then the sensitivity of each wavelength can be obtained according to the color difference ΔE.

1.2 Color displaying in time

On the basis of the relationship between tristimulus values of red, green and blue phosphors and the R, G, B values of the three electronic guns of the monitor of a computer system, eq. (1.5) can be obtained.[2]

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix}. \tag{1.5}$$

The corresponding RGB values for the target sample and the chosen prediction recipe can be calculated by the reverse equation of eq. (1. 5) and the two colors are displayed simultaneously on the color monitor to make a subjective evaluation in time.

2 Calculation and experiment

2.1 Method and result

The computer program based on eqs. (1.1)—(1.5) can be used to calculate the color difference ΔE in different situations, such as A ligh source or D65, different ΔR and various spectral reflectances of object. The interesting sensitivity of each wavelength is clear at a glance with the aid of ΔE-λ curve. All the ΔE-λ curves present generally a shape of double hump, meaning that there are three maxima and two minima in the middle of each curve besides the two ends of 400 and 700 nm. To take a priority to the more sensitive wavelengths of color may have some advantages in color match prediction. So a comparison between the selective wavelength method and the sixteen wavelengths method was first made in this study.

A comparison is shown in table 1.

Table 1

Method	Dye 1	Dye 2	Dye 2	Required time/s
Sixteen-wavelength	0.94	0.18	0.16	about 3.0
Three-wavelength	0 92	0.21	0.09	about 0 2

It is found that the two recipes are similar, but the required calculating times are remarkably different.

Table 2 gives a comparison of the calculated color difference between the two recipes in CIE1976Lab color space[3].

Table 2

Light source	A	D65
ΔEs, 16	1.170 5	0.891 5
ΔEs, 3	1.173 8	0.972 0
$\Delta E16$, 3	0.637 6	0.638 4

ΔEs, 16: a color difference based on the recipe by sixteen-wavelength method; ΔEs, 3: a color difference based on the recipe by three-wavelength method; $\Delta E16$, 3: the color difference between two recipes.

2.2 The error in color displaying

The tristimulus values of a color displayed on a monitor with a certain RGB values can be calculated using eq. (2.5) and measured using a trichromatic colorimeter. Two groups of tristimulus values are very close to each other; none of ΔX, ΔY and ΔZ is greater than 1.0[4].

3 Conclusion

1. The method of selecting three wavelengths of certain band is generally the same as the conventional sixteen-wavelength method in color match prediction.

2. The time taken to search for an ideal recipe by the wavelength-selecting method is much shorter than that by the conventional one. Saving time and cost is probably one of the advantages of the former method. So three-wavelength method could play an important role in computer color match prediction and in color measurement and line control.

3. The third-order transformation matrix based on eq. (1.5) can satisfy the requirements of displaying colors on a color monitor.

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